

INSTRUMENTATION FOR LOW LEVEL GALVANIC MEASUREMENTS

by

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GALVANIC MEASUREMENTS
INSTRUMENTATION FOR LOW LEVEL
ELECTRIC POTENTIAL MEASUREMENTS



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INTRODUCTION

There is an ever increasing tendency towards automation in measurement and control systems. Today it is often not acceptable to measure physical quantities transduced to analog forms such as length or angle. Instead, transducers used in modern measurement or control systems, almost exclusively deliver some form of electric signal. Energy in some form is converted into electric energy, thereby producing an electric analog signal. Many transducers are resistive, whereby it is understood that the resistance of the transducer is a function of another physical variable, e.g. temperature. An output signal of a relatively small magnitude is often produced.

The most critical part of a measurement system is the input stage, since the signal level at the input often is low. In many applications, particularly if an input voltage is to be integrated, a voltage to current convertor is a very good choice for an input stage. A detailed study of input circuit parameters such as the input offset voltage is necessary in most situations. A number of different voltage to current convertor types are analysed in the thesis.

A photomultiplier is frequently used for converting light intensity into an electric current. The output current from the photomultiplier may be less than 1 μA . If a high resolution and long term stability is required, particular care must be taken in the design of the input stage amplifier. A high performance instrument especially designed for a photometer system is described in the thesis.

A mercury-in-rubber strain gauge can be used to measure the volume pulsations of blood in a finger during a blood pressure test. In such an application the gauge is supplied with constant current, and the useful output signal voltage amplitude is approximately 350 μV . The signal is superimposed on a DC voltage of magnitude

120 mV, and a slowly varying signal of the order of 2 mV. A special electronically balanced bridge circuit is used in a blood pressure monitor described in the thesis.

In high current battery tests a current shunt is used to produce an output voltage proportional to the (dis)charging current. Even if this current is high, the output voltage from the shunt is usually rather low. This is due to the fact that the power dissipation in the shunt resistor must be kept below a certain limiting value. An instrumentation voltage to current convertor is used as the input stage of a battery test measurement system described in the thesis.

THE PRESENT THESIS INCLUDES THE FOLLOWING REPORTS:

- I. A digital current meter for measuring the anode current from a photomultiplier, LUIP-CR-74-18, Lund 1974. (In collaboration with B. Alvsten and K. Söderström).
- II. A Blood pressure monitor utilizing a mercury-in-rubber strain gauge, Department of physics, University of Lund, 1975. (In collaboration with E. Ljung).
- III. On voltage to current conversion, Department of physics, University of Lund, 1977.
- IV. Dual channel long term analog integrator and multiplier, Department of physics, University of Lund 1978.

SUMMARY

- I. The instrument is used in a nuclear track photometer system, in which the light absorption of particle tracks in nuclear emulsions is measured. The light transmitted through different

parts of the emulsion is detected by a photomultiplier [JÖNSSON et al 1970]. The instrument digitizes the photomultiplier current, and presents the result to a paper tape punch. An instrument with a large dynamic range, short settling time and high line frequency noise rejection is necessary in a measurement system of this type. The requirements were fulfilled by employing a current to frequency convertor for the digitization. Two prototypes of the instrument have been built, and measurements show that the full scale deviation is less than 100 ppm. over four decades of input current. The resolution of the instrument is 100 pA.

- II. An indirect method is used in ordinary routine measurements of human blood pressure. The vascular system in some part of a human limb, usually the upper arm, is occluded by means of an air cuff connected to a monitored pressure system. A stethoscope is used for detection of the noise produced by the blood penetrating the partly occluded vascular system. The pressure is rapidly raised to a suprasystolic level, which prevents the blood flow through the limb, and then slowly decreased. When the first sound is detected, the cuff pressure is equal to the maximum pressure in the vascular system at the position of the cuff. This value is denoted systolic pressure. The diastolic pressure is the minimum pressure in the vascular system, and this pressure is read at a sudden decrease in sound level.

The blood pressure in a finger can be measured by means of a small size air cuff and a mercury-in-rubber strain gauge that converts the volume pulsations of blood through the finger into an electrical signal [GUNDERSEN 1972]. An instrument that automatically performs a blood pressure measurement using the "mini-cuff" and a strain gauge has been designed. The instrument is triggered when the cuff pressure exceeds a variable starting level. The pressure is then decreased at a constant rate by means of a controlled needle-valve,

which regulates the air outlet from the pressure system. The signal from the strain-gauge, which is supplied with constant current, is digitized, and analysed digitally. At the first detectable peak in the gauge signal the cuff pressure is presented on a display as the systolic pressure. Similarly at the occurrence of maximum gauge signal amplitude, the cuff pressure is displayed as the diastolic pressure. Comparative measurements show a good correlation to the ordinary manual method.

- III. The report is a study of several voltage to current convertors. Most of the convertors are frequently used in modern electronic instrumentation. Simple linear models are used for active components, and by using these models the convertors are carefully analysed with respect to relevant performance figures, such as input offset voltage, relative conversion error, output resistance etc. In most cases, commonly specified data sheet parameters can be directly substituted into the derived expressions for the performance figures.

Two convertors developed by the author are presented and analysed. The first one is an "Instrumentation" circuit that is particularly useful in low level applications, where conventional unilateral circuits do not work properly due to induced line frequency noise. The second one is a drift compensated circuit [LJUNG 1975]. The input offset voltage is in this convertor periodically zeroed.

- IV. The instrument described in the report is primarily intended for use in battery test applications. It is a developed version of two other instruments presented earlier [ALVSTEN 1974] and [LJUNG 1975]. By means of two voltage to frequency convertors, interconnected in a "Current gating" configuration, the time integral of the product of two voltages is obtained [BERGLUND et al 1974]. It is shown in the report that six

measurement functions are realized with this type of circuit and some additional logic. In a battery test the six functions correspond to: the transferred charge and energy; the elapsed time; the charging or discharging current; the battery voltage and the power. The three first mentioned functions together with one of the last three functions can be performed simultaneously. The instrumentation voltage to current convertor (Part III) is implemented in one of the two voltage to frequency convertors. Measurements show that the performance at low input voltage levels is improved compared to earlier designs.

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